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The Automated City

Internet of Things and Ubiquitous Artificial Intelligence

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The first author dedicates this book to his one and only princess YC.
The second author dedicates this book to all past, present and future sentient beings who grace him with their unconditional love.

Imagination is more important than knowledge.

- Albert Einstein

Through wisdom a house is built;
by understanding it is established;
by knowledge the rooms are filled
with all rare and beautiful treasure.

- Proverbs 24:3-4 (WEB)

Sapientia urbs conditur
(In English: A city is built on wisdom)

- Motto of the University of Nottingham

Preface

We see, in the smartphone of today, a convergence of technologies, many drawing on decades of advances across many different areas of engineering and computing, including mobile and distributed computing, sensors, wireless networking, human-computer interaction, computer graphics, artificial intelligence, software engineering, operating systems, programming tools, and computer hardware design. As developments in smart city technologies continue, we also see a convergence of technologies in urban development, and in what we see every day in the city, such as vehicles and transportation systems. We wanted to capture in one place the excitement of computing technologies for the city of today and tomorrow.

We initially wanted to write a short book summarizing our current review of work in the areas of smart cities and automation in cities, with a focus on networked "physical agents" in the city such as urban robots, automated vehicles, and drones, biased towards our interests in the Internet of Things and transport (especially, road safety). We think such a book would be useful to researchers, innovators, and students researching and studying smart cities, Internet of Things, smart vehicles, smart things, artificial intelligence, robotics, drones, and other related areas, or anyone interested in these topics and their inter-connections, and wanting a "quick" overview, in one book.

But as we explored related technologies and their convergence, and the many perspectives on the smart city, we found many emerging and exciting ideas worthy of discussion. We take a broad and integrated perspective instead of piecemeal description of urban robots, automated vehicles, and drones in cities, thereby widening the scope, and with the publisher encouraging us to write a full-length book, this book is as it is now. We try to be comprehensive, but cannot be exhaustive, as there would be a wide range of links among different areas, technical, social, and ethical. The book can also be read by interested non-technical readers—we do not dwell into algorithmic or technical details, keeping the book largely readable by a broad audience, or at least an audience with an interest in technology and how they might be used in cities of the future. Also, this book can be a starting point for those who would like an introductory overview of the areas and how they connect. Some of the topics in this book we have only briefly touched on—for the reader keen to

go into technical details, we provide numerous references from the scientific peer-reviewed and grey literature.

Also, an aim of this book is to identify, highlight, and define the notion of the Automated City, as it continues to take shape and evolve among the many perspectives on the smart city. We also discuss metaphors and ways of thinking about the Automated City, at least from the technological perspective.

It must be said from the start that the book does not attempt to forecast or envision all aspects of the future city—this would be too difficult a task and prone to error. After all, who knows really what the future will bring. (However, we note that Alan Kay's maxim "the best way to predict the future is to invent it" is perhaps one way to see, at least, some aspect of the future—that is, the part which we invent.)

Instead, the book attempts a review of topics related to the notion of the smart city, with a particular focus on technology areas that we have worked on and have an interest in. We attempted to highlight what we call the Automated City, in the context of other work (and perspectives) in the smart city area, e.g., work on the Participatory City and the Data-Centric City. At certain points, we do try to extrapolate from current developments to consider how things can develop, and ask "what-if" questions, and discuss issues that would arise as a result. There are many places in the book where we used "can" and "could" to point out possibilities, about what can happen, and what could happen, not necessarily what will happen (we try not to pretend we can predict the future there, as we certainly cannot!). One might consider some aspects of the book as rather speculative, but we, as researchers, are trying to be exploratory, and write about possibilities. The book discusses opportunities and issues that can arise with the use of certain technologies for the Automated City, not so much a book of solutions. We also introduce some of our own ideas for the Automated City, such as massive cooperation of smart things in the city, and the issues therein. If forced to choose between problem solvers and problem creators, we would be largely problem identifiers in this book. Hence, the book might be of interest to someone looking for challenges to address! In Chap. 1 of this book, we provide an overview of technology trends, many of which have or are being applied to make cities "smarter". As we embarked on the book, the COVID-19 pandemic happened, which had an enormous social, mental, and economical impact on lives throughout the world. Over a year later, it is still not over as we pen the conclusion of this book. A question then arises is how the Automated City could help in a pandemic-stricken world. One could think of how automation could help keep certain important functions in the city going, from food supply chain to waste management, but answering this question is a much broader and bolder ambition than what this book can achieve (and certainly not the intent of this book). Instead, we devote a whole section in this chapter to exploring how people have used technology in the city during the pandemic situation. Many of the ideas and technologies we discuss are prototype deployments and pioneering, and some are more mature. While not an exhaustive review of technology use for the pandemic, the book highlights examples of automation and how they can help in pandemic situations— while not a water-tight argument for the importance of automation in the city, our review illustrates possibilities and suggests some technology directions

in the city that could outlive the pandemic. Finally, the chapter provides a brief overview of conceptualizations of the smart city, introducing the theme of the book, which is the Automated City—it is not intended to be a theme that should supersede other perspectives, but only one perspective among many for looking at the smart city concept.

Chapter 2 discusses the concept of the Automated City in detail and introduces a number of metaphors for the Automated City. We first consider the automation of large-scale city systems, the availability of data enabling proactive and reactive cities, self-repairing cities, and urban robots. Then, we consider the metaphor of the Automated City as partner, as host and as art, in relation to its inhabitants. The metaphors highlight the collection of autonomous entities (from vehicles to robots) in the city, taken as a whole, on one side, and the human inhabitants, on the other side, and consider how they relate. The metaphors act as "lenses" through which one can view the Automated City concept. We conclude the chapter by providing a definition of the Automated City.

Chapter 3 takes a deep dive into three types of technologies, namely, automated vehicles, drones (or UAVs, short for unmanned aerial vehicles), and urban robots. We discuss their potential benefits and applications, and their issues and limitations. We choose these three technologies mainly because we have been active in some aspects of their development, and they are easily visible (and tangible) technologies that illustrate how the Automated City could develop. These technologies could, if they proliferate, occupy a large part of the public physical space in the city and are often easily noticeable. While we see their potential and look forward to their future development, we try to provide a balanced view of both their promises and issues (even their perils!).

After the focus on specific technologies, Chap. 4 takes a step back and considers the broader concerns of the development of a city. We review visions of future cities and point out issues of the governance of automation and the automation of governance. We briefly discuss new business models, city transportation, sustainability, real-time tracking, and urban edge computing. Finally, we also discuss the challenges of massive cooperation and the broad range of issues of trust and ethics in relation to the use of AI and smart devices (in private or public) in the city.

Finally, in Chap. 5, we conclude on a more philosophical and reflective note.

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June 2021

Acknowledgements

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About the Authors

Professor Seng W. Loke received his BSc (First Class Hons.) degree in computer science from the Australian National University and PhD degree in computer science from the University of Melbourne, Australia, in 1994 and 1998, respectively. He is currently professor in computer science within the School of Information Technology at Deakin University, Australia. He currently co-directs the Platforms and Applications Lab, in the Centre for Internet of Things ECOsystems Research and Experimentation (CITECORE) at Deakin's School of Information Technology. His research interests include the Internet of Things, cooperative vehicles, mobile computing, crowd computing, smart city, and social impacts of information technology. He authored *Context-Aware Pervasive Systems: Architectures for a New Breed of Applications* published by Auerbach (CRC Press), Dec 2006, and more recently authored Crowd-Powered Mobile Computing and Smart Things published by Springer in 2017.

Professor Andry Rakotonirainy received his PhD degree in computer science from Sorbonne University and INRIA (French National Institute for Research in Digital Science and Technology) in 1995. He is currently the director of the Centre for Accident Research and Road Safety Queensland (CARRS-Q) and founder of its Intelligent Transport Systems (ITS) human factors research program. He has 25 years' research and management experience in computer science, road safety, and ITS design and implementation. He is currently a member of the Australian Research Council (ARC) College of Experts and is a regular member of EU-funded research projects' advisory boards. Professor Rakotonirainy's research has been recognised both nationally and internationally. He has proactively investigated the use of existing and emerging ITS from multiple disciplines such as computer science, mathematics, human factors, engineering, psychology, and sociology.

Chapter 1
An Overview of Technology Trends Towards Smarter Cities

Abstract The chapter discusses the rise of technology usage in cities, and how the recent COVID-19 crisis provided an opportunity for technologists to meaningfully consider how their technologies could be useful in cities. We also provide an overview of current technology trends such as AI and robotics, Internet of Things, Intelligent Transport Systems, Automated Vehicles, City Platforms, as well as their applications to smart cities. The chapter provides an integrative overview of Information and Communication Technologies (ICT) related to making cities smarter. Against the backdrop of the technology trends, this chapter positions the concept of the Automated City within current conceptualisations of the Smart City, including smart city standards and participatory and data-centric views of the smart city.

1.1   The Rise of Automation

A fundamental human need is arguably to be happy. We all need a comfortable shelter and social setting where we can fulfil our needs and reach our potential. Cities are increasingly attracting newcomers as they promise stable environments offering basic food and shelter for families as well as rich infrastructure and services to satisfy emotional needs and the desire for comfort. Etymologically speaking, the word *city* originated from the Latin *civitas*. Civitas refers to the legal status of a citizen belonging to a community and the territory occupied by this community.

Cities are places of belonging for many, with their construction and lives aided by increasingly sophisticated machinery. Contrary to common belief, automation is not a concept from the industrial revolution. It dates back to ancient Greek mythology. Hephaestus (in Homer's *Illiad*), the Greek god of invention, constructed automatons crafted out of metal to help him in his workshop in order to perform various tasks. Conceptually, they can be viewed as self-operating machines or robots. Indeed, as reviewed by Mayor in [32], automata, ideas of Artificial Intelligence, and human enhancements, have been envisioned in ancient Greek, Indian, Roman, and Chinese mythology.

Automation refers to man-made machines, such as computers or robots, that have been programmed to carry out tasks to assist humans or on behalf of humans. It is important to note that the assistive mission of robots, no matter how advanced the automation, there is always a human or a team behind it (e.g., the developer, or controller).

Our contemporary use of *Automated City* covers how the citizens of a city are assisted by automation and how citizens' daily life change as a result. It does not refer to a completely roboticized city emptied of its humane nature. Indeed, the role of automation is to make cities *better for* humans, not to constrain humans or make cities *without* humans.

The Automated City is the intersection of urbanity and ingenuity brought about by automated technology to empower its citizens.

Over the centuries, the development of technology, which incidentally also has its etymology in the Greek *tekhnologia* for "systematic treatment of an art, craft, or technique",[1] especially information technology, is bringing ancient visions into reality (even if not intentionally so).

1.2 The Rise of Smart Cities

Today, the world is largely urban, and will be increasingly so. About 55% of the world today live in urban areas and this is projected to rise to 70% in the coming three decades.[2] Australia, in particular, despite its large geographical size, has over 65% of its population living in capital cities and 23% in other urban areas, that is, over 88% of its population live in urban areas.[3]

Urbanisation itself takes different forms, with different sizes of cities, and different characteristics, growing not just outwards (e.g., the urban sprawl) and upwards (e.g., the skyscrapers of increasing heights), but also inwards with changes within. As noted by Batty in [6], there are waves of development (also called the *Kondratieff wave*, named after a Soviet economist) when considered from the Industrial Revolution onwards, the first wave from around 1775 based on the invention of steam power and combustion engines, the second wave based on rail power and large-scale manufacturing in the 1800s, the third wave was the age of the electricity till the early 1900s, the fourth wave was marked by the automobile, aircraft, and the early stages of computing till 1975, the fifth wave from 1975 onwards is characterised by global communications and the pervasiveness of computing as we see today, and as argued by Batty, the sixth wave will be:

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[1]https://www.etymonline.com/word/technology [last accessed: 30/6/2020].

[2]https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html [last accessed: 30/6/2020].

[3]https://www.abs.gov.au/websitedbs/D3310114.nsf/home/Interesting+Facts+about+Australia%E2%80%99s+population [last accessed: 30/6/2020].

strongly associated with digital technologies applied to cities, medicine, security, and many other aspects of everyday life, notwithstanding the massive automation that will define society from now on.

Batty goes on to say that this sixth wave is "the age of the smart city."

The association of smart city with technology is not surprising, given its history.[4] Cities continue to be areas of rapid development as large cities get larger, so that problems of congestion and resource management persist, while cities continue to allow increasing opportunities and attract newcomers.[5] There is then the increasing need for cities and its citizens to get smarter, not only in the use of resources but also in managing city issues and in increasing the quality of city life; a collection of solutions and technological tools (e.g., smart apps) rooted in the rapid developments of information technology and communications have become a common approach. For example, to consider just four application areas, taken from [62], we have the following smart city application areas:

- *security*: example applications include "predictive policing", "real-time crime mapping", "gunshot detection", "smart surveillance", "emergency response optimization", "body-worn cameras", "disaster early-warning systems", "personal alert applications", "home security systems", "data-driven building inspections", "crowd management";
- *mobility*: example applications include "real-time public transit information", "digital public transit payment", "autonomous vehicles", "predictive maintenance of transportation infrastructure", "intelligent traffic signals", "congestion pricing", "demand-based microtransit", "smart parking", "e-hailing (private and pooled)", "car sharing", "bike sharing", "integrated multimodal information", "real-time road navigation", "parcel load pooling", "smart parcel lockers";
- *waste management*: we have "digital tracking and payment for waste disposal", and "optimization of waste collection routes"; and
- *water management*: we have "water consumption tracking", "leakage detection and control", "smart irrigation", and "water quality monitoring".

Other application areas include health, energy, community engagement and housing, with technologies for in-home care, air-quality monitors, digital services apps, technologies used for smart energy monitoring, building automation and smart street-lighting. Not every smart city employs all of such tools; and there are other listings of such smart city tools and applications.[6] But they are suggestive of the rise of technologies in managing cities. Such tools have benefits and have provided some improvements in urban life. We will look at some of the above technologies (e.g., for mobility) in greater depth later in the book.

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[4]https://www.verdict.co.uk/smart-cities-timeline/ [last accessed: 30/6/2020].

[5]https://www.forbes.com/sites/deborahtalbot/2018/09/12/why-cities-get-the-best-jobs/#33710b821492 [last accessed: 30/6/2020].

[6]Also, see the list of smart city tools at https://smartcitiescouncil.com/taxonomy/term/558 [last accessed: 30/6/2020].

While smart cities are generally characterised by the heavy use of information and computing technologies in an increasing number of aspects of city life, smart cities are not merely collections of applications. As noted by Halegoua in [20]:

> ...technology alone will not fundamentally transform urban governance or necessarily improve quality of life for all residents. ...Technological solutions are not wholly capable of fixing underlying conditions that lead to urban inequalities and inadequate service provisions.

Social inclusion is among the fundamental properties that smart cities need to uphold. Smart environments such as ubiquitous computing and new innovative services have been used to encourage and facilitate inclusion where the city turns into a digital platform imbued with a sense of citizen engagement.

Later in the book, we will explore and discuss further different conceptualisations of smart cities.

1.3   Technology in Cities in the Midst of a Pandemic

However, just in the midst of flourishing, as we started on this book, many cities around the world were hit by the COVID-19 pandemic, and many countries were responding to it in drastic ways.

The pandemic is a shock to all of us. However, the uncertainty caused by COVID-19 generated a larger, unprecedented shock-wave disrupting all layers of our society. Such uncertainty raises the question of how to sustain city life.

We observed an unprecedented increasing uptake of technology at work, education, governance, medical care, and a wide range of businesses migrated online, albeit some only temporarily, in a massive way. Elderly citizens who had no need to use particular technology would now employ Zoom to talk to their family members who could not visit them in-person due to social distancing restrictions. Children normally used to in-person classrooms have to resort to tablets and iPads for their educational needs. Cloud computing companies and online meeting providers enjoyed a tremendous growth in uptake during this time, while the travel industry (and related industries) suffered. Life seemed to be happening more in cyberspace than in physical space, in a "new normal". In a way, in a short time, cities had undertaken a transformation into being more technologically supported or dependent, perhaps at a pace faster than typical (which one might say is already fast), facilitated by computing and information technology as well as increasing connectivity. This sudden leap to technology adoption has surpassed the wildest expectations of researchers and developers who have been working on technology acceptance for years.

One might wonder if such technology is an important ingredient for providing the capability of a city to adapt to sudden changes such as COVID-19.

For technologists, the challenging times also called for an answer to the question of how the many exciting fairly recent developments in computing and related

fields, from the Internet of Things (IoT) to Artificial Intelligence (AI), and their convergence, can be used to help the COVID-19 pandemic situation. The question is relevant beyond the context of COVID-19, i.e. the question of the the impact of such technologies in society, in general. The answer is, in fact, multifaceted, and not without wide-ranging societal implications.

Automation alone, it must be noted, will not spontaneously improve our city life, but COVID-19 has accelerated the adoption of various kinds of technologies, including video conference technology. Microsoft's CEO Satya Nadella noted that we have achieved in two months what it would have taken two years to happen:[7] "We've seen two years' worth of digital transformation in two months. From remote teamwork and learning, to sales and customer service, to critical cloud infrastructure and security—we are working alongside customers every day to help them adapt and stay open for business in a world of remote everything." However, it seems that we have missed the opportunity to use other technologies, such as Automated Cars, to help people cope with some aspects of COVID-19 on a large scale (as the technology and regulations are still maturing).

Nevertheless, given the impact and scale of COVID-19 in cities around the world, we consider some technological applications that have been seen in popular press[8] in the following subsections.

1.3.1   Robots Helping to Deal with Infectious Diseases

At the Providence Regional Medical Center, a robot suitably equipped with a camera, stethoscope and microphone was used by doctors to interact with quarantined people—the robot is moved around by nursing staff and is not completely autonomous.[9] At the Wuchang field hospital, 5G-powered bots are used to take patients' temperatures, deliver meals and disinfect the facility.[10] Robots for cleaning areas include the germ-zapping robot Xenex[11] and robots for cleaning aeroplane cabins such as the UV-C Light system.[12] A robot developed by MIT used a custom

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[7]https://www.microsoft.com/en-us/microsoft-365/blog/2020/04/30/2-years-digital-transformation-2-months/ [last accessed: 2/10/2020].

[8]Many are highlighted in https://www.linkedin.com/pulse/amazing-ways-robots-drones-helping-fight-covid-19-bernard-marr/ and in
https://economictimes.indiatimes.com/news/science/coronavirus-fighting-robots-and-drones/sanitizing-toilet/slideshow/75656015.cms [last accessed: 30/6/2020].

[9]https://www.medicaldevice-network.com/features/coronavirus-robotics/   [last   accessed: 30/6/2020].

[10]https://nypost.com/2020/03/10/coronavirus-hospital-ward-staffed-by-robots-opens-in-wuhan-to-protect-medics/ [last accessed: 30/6/2020].

[11]https://www.xenex.com/our-solution/lightstrike/ [last accessed: 30/6/2020].

[12]https://www.ainonline.com/aviation-news/aerospace/2020-04-27/uv-c-light-system-eliminates-covid-19-aircraft-cabins [last accessed: 30/6/2020].